

We claim:

1. A transgenic plant, wherein at least a part of said plant has an increased specific activity of thioredoxin in comparison to the same part of a non-transgenic plant of the same species.
5. The transgenic plant of claim 1, wherein said thioredoxin specific activity is at least twice the specific activity of thioredoxin in said non-transgenic plant of the same species.
10. The transgenic plant of claim 1, wherein said thioredoxin specific activity is at least five times the specific activity of thioredoxin in said non-transgenic plant of the same species.
15. The transgenic plant of claim 1, wherein said thioredoxin specific activity is at least ten times the specific activity of thioredoxin in said non-transgenic plant of the same species.
5. The transgenic plant of claim 1, wherein said thioredoxin is thioredoxin *h*.
6. The transgenic plant of claim 6, wherein said thioredoxin *h* is is barley, wheat, *Arabidopsis*, tobacco, rice, *Brassica*, *Picea*, or soy bean thioredoxin *h*.
20. The transgenic plant of claim 1, wherein said specific activity of thioredoxin is at least 0.128 $A_{340\text{nm}} / \text{min/mg protein}$.
25. A transgenic plant, wherein at least a part of said plant has increased thioredoxin protein content in comparison to the thioredoxin protein in the same part of a non-transgenic plant of the same species.
9. The transgenic plant of claim 8, wherein said thioredoxin protein is thioredoxin *h* protein.
10. The transgenic plant of claim 8, wherein said thioredoxin *h* protein is barley, wheat, *Arabidopsis*, tobacco, rice, *Brassica*, *Picea*, or soy bean thioredoxin *h*.
30. The transgenic plant of claim 8, wherein said thioredoxin protein content is at least 10 $\mu\text{g}/\text{mg}$ soluble protein.
35. 12. A transgenic plant, wherein at least part of said plant has an increased SH:SS ratio in comparison to the same part of a non-transgenic plant of the same species.
13. The transgenic plant of claim 12 wherein said SH:SS ratio is at least 5:1.

14. The transgenic plant of claims 1, 8, or 12 wherein said plant is selected from the group consisting of rice, barley, maize, wheat, oat, rye, sorghum, millet, triticale, and forage and turf grass.

5 15. A transgenic plant, wherein at least part of said plant has reduced allergenicity in comparison to the same part of a non-transgenic plant of the same species.

10 16. The transgenic plant of claim 15 wherein said allergenicity is hypersensitivity, wherein said hypersensitivity is reduced by at least 5%.

15 17. A transgenic plant, wherein at least part of said plant has an increased digestibility in comparison to the same part of a non-transgenic plant of the same species.

20 18. The transgenic plant of claim 17 wherein said digestibility is increased by at least 5%.

25 19. The transgenic plant of claim 15 or 17, wherein said transgenic plant is selected from the group consisting of rice, barley, maize, wheat, oat, rye, sorghum, millet, triticale, and forage and turf grass.

30 20. A transgenic plant, wherein at least part of said plant has an earlier onset and/or an increased expression of a gibberellic acid inducible enzyme in comparison to the same part of a non-transgenic plant of the same species.

35 21. The transgenic plant of claim 20 wherein said enzyme is pullulanase.

22. The transgenic plant of claim 21 wherein said pullulanase has a specific activity of at least 1-2 absorbance units at 534 nm/30 min/mg protein.

23. The transgenic plant of claim 20 wherein said enzyme is alpha-amylase.

24. The transgenic plant of claim 23, wherein said alpha-amylase is expressed in said plant is at least 8 hours before expression in said non-transgenic plant of the same species.

25. The transgenic plant of claim 23 wherein said alpha-amylase is alpha-amylase A.

26. The transgenic plant of claim 23 wherein said alpha-amylase is alpha-amylase B.

27. The transgenic plant of claim 20, wherein said transgenic plant is barley.

28. The transgenic plant of claims 1, 8, 12, 15, 17, or 20 wherein said part is an edible part.

29. The transgenic plant of claim 28, wherein said edible part is a grain.

5 30. The transgenic plant of claim 28, wherein said edible part is a seed.

31. The transgenic plant of claims 1, 8, 12, 15, 17, or 20 wherein said part of said transgenic plant comprises a recombinant nucleic acid expressing a thioredoxin polypeptide.

10 32. A transgenic plant wherein at least part of said plant comprises a recombinant nucleic acid comprising a promoter active in said part operably linked to a nucleic acid molecule encoding a thioredoxin polypeptide.

15 33. The transgenic plant of claim 32 wherein said part is a seed.

34. The transgenic plant of claim 32 wherein said part is a grain.

20 35. The transgenic plant of claim 32 wherein said promoter is a seed or grain maturation-specific promoter.

25 36. The transgenic plant of claim 35 wherein said promoter is selected from the group consisting of rice glutelins, rice oryzins, rice prolamines, barley hordeins, wheat gliadins, wheat glutelins, maize zeins, maize glutelins, oat glutelins, sorghum kasirins, millet pennisetins, rye secalins, and a maize embryo-specific globulin promoter.

30 37. The transgenic plant of claim 36 wherein said barley hordein promoter is selected from the group consisting of B1 hordein and D hordein promoters.

38. The transgenic plant of claim 32 wherein said plant is selected from the group consisting of rice, barley, maize, wheat, oat, rye, sorghum, millet, triticale, turf-grass and forage grass.

35 39. The transgenic plant of claim 32 wherein said thioredoxin is thioredoxin h.

40. The transgenic plant of claim 39 wherein said thioredoxin h is barley, wheat, tobacco, rice, *Brassica*, *Arabidopsis*, *Picea*, or soy bean thioredoxin h.

41. The transgenic plant of claim 32 wherein said recombinant nucleic acid further comprises a nucleic acid molecule encoding a signal peptide operably linked to said promoter and said

nucleic acid molecule encoding a thioredoxin protein.

5 42. The transgenic plant of claim 41 wherein said signal peptide targets expression of the thioredoxin polypeptide to an intracellular body.

10 43. The transgenic plant of claim 42 wherein said signal peptide is selected from the group consisting of barley B1 hordein and D hordein signal peptides.

15 44. A transgenic seed or grain comprising an increased specific activity of thioredoxin in comparison to a non-transgenic seed or grain of the same species.

20 45. The transgenic seed or grain of claim 44, wherein said specific activity of thioredoxin is at least twice the specific activity of thioredoxin in said non-transgenic seed or grain of the same species.

25 46. The transgenic seed or grain of claim 44, wherein said specific activity of thioredoxin is at least five times the specific activity of thioredoxin in said non-transgenic seed or grain of the same species.

30 47. The transgenic seed or grain of claim 44, wherein said specific activity of thioredoxin is at least ten times the activity of thioredoxin in said non-transgenic seed or grain of the same species.

35 48. The transgenic seed or grain of claim 44, wherein said thioredoxin is thioredoxin *h*.

49. The transgenic seed or grain of claim 48, wherein said thioredoxin *h* is barley, wheat, tobacco, soy bean, *Arabidopsis*, *Picea*, or *Brassica* thioredoxin *h*.

50. The transgenic seed or grain of claim 44, wherein said specific activity of thioredoxin is at least $0.128 A_{340nm}/\text{min}/\text{mg protein}$.

51. A transgenic seed or grain comprising increased content of thioredoxin polypeptide in comparison to a non-transgenic seed or grain of the same species.

52. The transgenic seed or grain of claim 51 wherein said content of thioredoxin polypeptide is at least $10 \mu\text{g}/\text{mg soluble protein}$.

53. The transgenic seed or grain of claim 51, wherein said thioredoxin polypeptide is thioredoxin *h* polypeptide.

34. The transgenic seed or grain of claim 53, wherein said thioredoxin *h* polypeptide is barley, wheat, tobacco, rice, *Brassica*, *Picea*, soy bean, or *Arabidopsis* thioredoxin *h* protein.

5 55. A transgenic seed or grain comprising an increased SH:SS ratio in comparison to a non-transgenic seed or grain of the same species.

10 56. The transgenic seed or grain of claim 55, wherein said SH:SS ratio is at least 5:1.

15 57. The transgenic seed or grain of claims 44, 51, or 55 wherein said seed or grain is selected from the group consisting of rice, barley, maize, wheat, oat, rye, sorghum, millet, triticale, forage grass and turf grass.

20 58. A transgenic seed or grain comprising reduced allergenicity in comparison to a non-transgenic seed or grain of the same species.

25 59. The transgenic seed or grain of claim 58 wherein said allergenicity is hypersensitivity, wherein said hypersensitivity is reduced by at least 5%.

60. A transgenic seed or grain comprising increased digestibility in comparison to a non-transgenic seed or grain of the same species.

30 61. The transgenic seed or grain of claim 60 wherein said digestibility is increased by at least 5%.

62. The transgenic seed or grain of claim 58 or 60, wherein said transgenic seed or grain is wheat, barley, rice, maize, oat, rye, sorghum, millet, triticale, forage grass or turf grass seed or grain.

35 63. A transgenic seed or grain overexpressing a thioredoxin protein comprising an earlier onset and/or an increased expression of a gibberellic inducible enzyme in comparison to a non-transgenic seed of the same species.

64. The transgenic seed or grain of claim 63, wherein said seed or grain is germinated and wherein said enzyme is pullulanase.

65. The transgenic seed or grain of claim 64 wherein said pullulanase has a specific activity of at least 1-2 absorbance units at 534 nm/30 min/mg protein.

30 66. The transgenic seed or grain of claim 63 wherein said enzyme is alpha-amylase.

67. The transgenic seed or grain of claim 66 wherein said alpha-amylase is expressed in said seed or grain at least 8 hours before expression in said non-transgenic plant of the same species.

68. The transgenic seed or grain of claim 66 wherein said alpha-amylase is alpha-amylase A.

5 69. The transgenic seed or grain of claim 66 wherein said alpha-amylase is alpha-amylase B.

70. A transgenic seed or grain having an increased germination rate in comparison to a non-transgenic seed or grain of the same species.

10 71. A transgenic seed or grain having an onset of germination that occurs at least 8 hours prior to the onset of germination of a non-transgenic seed or grain of the same species.

15 72. A transgenic seed or grain wherein said seed or grain germinates 5% more efficiently than a non-transgenic seed or grain of the same species.

20 73. The transgenic seed or grain of claim 63, 70, 71, or 72 wherein said transgenic seed or grain is a barley seed.

25 74. A transgenic seed or grain overexpressing a thioredoxin, wherein protein of said seed or grain are redistributed at least 5% greater to the soluble fraction in comparison to a non-transgenic seed or grain of the same species.

75. The transgenic seed or grain of claim 74, wherein said transgenic seed or grain is a wheat, barley, rice, maize, oat, rye, sorghum, millet, triticale, forage grass or turf grass seed or grain.

30 76. The transgenic seed or grain of claim 44, 51, 55, 58, 60, 63, 70, 71, 27, or 74 wherein said transgenic seed or grain comprises a recombinant nucleic acid expressing a thioredoxin polypeptide.

35 77. A transgenic seed or grain comprising a recombinant nucleic acid comprising a promoter active in said seed or grain operably linked to a nucleic acid molecule encoding a thioredoxin polypeptide.

78. The transgenic seed or grain of claim 77 wherein said promoter is a seed or grain maturation-specific promoter.

36 79. The transgenic seed or grain of claim 78 wherein said promoter is selected from the group

B1 *crossed*
consisting of rice glutelins, rice oryzins, rice prolamines, barley hordeins, wheat gliadins, wheat glutelins, maize zeins, maize glutelins, oat glutelins, sorghum kasirins, millet pennisetins, rye secalins, and a maize embryo-specific globulin.

5 *Sur* *80*
80. The transgenic seed or grain of claim 79 wherein said barley hordein promoter is selected from the group consisting of B1 hordein and D hordein promoters.

10 *Sur*
81. The transgenic seed or grain of claim 80 wherein said seed or grain is selected from the group consisting of rice, barley, maize, wheat, oat, rye, sorghum, millet, and triticale seed or grain.

15 *Sur* *82*
82. The transgenic seed or grain of claim 77 wherein said thioredoxin polypeptide is thioredoxin-*h*.

20 *Sur* *83*
83. The transgenic seed or grain of claim 82 wherein said thioredoxin *h* is barley, wheat, tobacco, rice, soy bean, *Brassica*, *Picea*, or *Arabidopsis* thioredoxin-*h*.

25 *Sur* *84*
84. The transgenic seed or grain of claim 77 wherein said recombinant nucleic acid further comprises a nucleic acid molecule encoding a signal peptide operably linked to said promoter and said nucleic acid molecule encoding a thioredoxin protein.

30 *Sur* *85*
85. The transgenic seed or grain of claim 84 wherein said signal peptide targets expression of the thioredoxin polypeptide to an intracellular body.

35 *Sur* *86*
86. The transgenic seed or grain of claim 85 wherein said signal peptide is selected from the group consisting of barley B1 hordein and D hordein signal peptides.

87. A food, feed or beverage product made from the transgenic seed or grain according to claim 44, 51, 55, 58, 60, 63, 70, 71, 77, or 84.

88. The food, feed, or beverage product of claim 87 wherein said product is flour, dough, bread, pasta, cookies, cake, thickener, beer, malted beverage, or a food additive.

89. The food, feed, or beer product of claim 87 wherein said product has reduced allergenicity.

90. The food, feed, or beverage product of claim 89 wherein said product has increased digestibility.

91. The food product of claim 88 wherein said dough has increased strength and volume in comparison to a dough made from a non-transgenic seed or grain of the same species.

92. The food product of claim 91 wherein said dough has an increased volume of at least 3% in comparison to a dough made from a non-transgenic seed or grain of the same species

93. A transgenic plant produced from the seed or grain according to claim 44, 51, 55, 58, 60, 63, 70, 71, 77, or 84.

94. A method of making a transgenic plant comprising cultivating the transgenic seed or grain according to claim 44, 51, 55, 58, 60, 63, 70, 71, 77, or 84.

95. A method of making a transgenic plant, wherein at least a part of said plant has an increased thioredoxin specific activity in comparison to a non-transgenic plant of the same species, comprising: expressing in said part a recombinant nucleic acid comprising a nucleic acid molecule encoding a thioredoxin polypeptide operably linked to transcription regulatory elements active in said part.

96. A method of making a transgenic plant, wherein at least a part of said plant has increased thioredoxin protein content in comparison to a non-transgenic plant of the same species, comprising: expressing in said part a recombinant nucleic acid comprising a nucleic acid molecule encoding a thioredoxin polypeptide operably linked to transcription regulatory elements active in said part.

97. A method of making a transgenic plant, wherein at least a part of said plant has an increased SH:SS ratio in comparison to a non-transgenic plant of the same species, comprising: expressing in said part a recombinant nucleic acid comprising a nucleic acid molecule encoding a thioredoxin polypeptide operably linked to transcription regulatory elements active in said part.

98. A method of making a transgenic plant, wherein at least a part of said plant is less allergenic in comparison to a non-transgenic plant of the same species, comprising: expressing in said part a recombinant nucleic acid comprising a nucleic acid molecule encoding a thioredoxin polypeptide operably linked to transcription regulatory elements active in said part.

99. A method of making a transgenic plant, wherein at least a part of said plant has an increased digestibility in comparison to a non-transgenic plant of the same species, comprising: expressing in said part a recombinant nucleic acid comprising a nucleic acid molecule encoding a thioredoxin polypeptide operably linked to transcription regulatory elements active in said part.

100. A method of making a transgenic plant, wherein at least a part of said plant has an altered expression of a gibberellic acid inducible enzyme in comparison to a non-transgenic plant of the

same species, comprising: expressing in said part a recombinant nucleic acid comprising a nucleic acid molecule encoding a thioredoxin polypeptide operably linked to transcription regulatory elements active in said part.

5 101. The method according to any one of claims 95-100, wherein said part is a seed or grain.

10 102. A method of altering the germination characteristics of a seed or grain comprising: germinating a seed comprising a recombinant nucleic acid comprising a nucleic acid molecule encoding a thioredoxin polypeptide operably linked to transcription regulatory elements active in said seed or grain.

15 103. A method of alleviating or preventing a malabsorption syndrome or an allergy comprising feeding a patient having said syndrome or allergy a food product made from the transgenic seed or grain according to claim 44, 51, 55, 58, 60, 63, 70, 71, 77, or 84.

20 104. A method of producing alcohol comprising: fermenting the transgenic seed or grain according to claim 44, 51, 55, 58, 60, 63, 70, 71, 77, or 84.

25 105. A method of producing malt comprising: germinating the transgenic seed or grain according to claim 44, 51, 55, 58, 60, 63, 70, 71, 77, or 84. under conditions whereby malt is produced.

106. A method of purifying thioredoxin comprising: heating an extract of a transgenic plant, wherein said plant has increased thioredoxin protein in comparison to a non-transgenic plant of the same species, whereby NADPH oxidation of said extract is substantially decreased and said thioredoxin is purified.

107. The method of claim 106 wherein said thioredoxin protein is active thioredoxin protein.

30 108. A food, feed, or beverage comprising a part of a transgenic plant or an extract of said part wherein said part comprises a recombinant nucleic acid comprising a sequence encoding a thioredoxin operably linked to transcription regulatory sequence operable in said part.

109. The food, feed, or beverage of claim 108 wherein said food, feed, or beverage has hyperdigestible protein.

35 110. The food, feed, or beverage of claim 108 wherein said food, feed, or beverage has hyperdigestible starch.

111. The food, feed, or beverage of claim 108 wherein said food, feed, or beverage is hypoallergenic.

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